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ABSTRACT

A major issue concerning adult intellectual development is whether intellectual decline in late adulthood is uniform or ability-specific. Differential patterns of ability decline were analyzed by comparing data on longitudinal age change over the age range from 53 to 81 years from two successive 14-year periods (1956-1970 and 1970-1984). The abilities considered were Verbal Meaning, Spatial Orientation, Inductive Reasoning, Number Skills, and Word Fluency. Subjects (N=229) for whom data were available over the 1970-1984 period were administered a battery of tests and were assigned to five sessions of cognitive training on one target ability (Inductive Reasoning or Spatial Orientation) and practice on the remaining abilities. Two weeks after training, subjects were re-administered the test battery. The data replicated earlier findings that significant age decrement does not begin until age 60. Patterns of decline differed in level by cohort and, for Word Fluency, also in rate of decline. Practice reversed average performance drops from age 53 to 67 on all abilities except Number, and reversed performance drops from age 60 to 74 on Verbal Meaning, Spatial Orientation, and Word Fluency. Cognitive training further reversed the drop on Inductive Reasoning from age 60 to 74, and reversed the drop on Spatial Orientation and Inductive Reasoning from age 67 to 81. (Author/NRB)

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DIFFERENTIAL ABILITY DECLINE AND ITS REMEDIATION IN LATE ADULTHOOD

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Abstract

This presentation analyzes differential patterns of ability decline by comparing data on longitudinal age change over the age range from 53 to 81 years from twosuccessive fourteen year periods (1956-1970 and 1970 to 1984). The most recent data once again replicate findings that significant age decrement does not begin until age 60. Patterns of decline differ in level by cohort and at least for one ability (Word Fluency) also in rate of decline. 229 study participants received cognitive training on one target ability (Inductive Reasoning or Spatial Orientation) and practice on the remaining abilities. Practice sufficed to reverse average performance drops from age 53 to 67 on all abilities except Number, and performance drops from age 60 to 74 on Verbal Meaning, Spatial Orientation and Word Fluency. Cognitive training further reversed the drop on Inductive Reasoing from 60 to 74, and the drop on Spatial Orientation and Inductive Reasoning from age 67 to 81. An examination of score distributions for those subjects who reliably declined showed a fourteen year drop for about 40% of the scores below the 1970 base; about two thirds of this drop was reversed by practice and training. For those remaining stable, practice and training raised about 20% of the scores above the 1970 base distribution.

This research was supported by grants AG03544 and AG04770 from the National Institute of Aging. The cooperation of members and staff of the Group Health Cooperative of Puget Sound is gratefully acknowledged. Thanks are due also to Diane Backschiess, Jean Day, Jackie Levine, Cherril Perera, Alejandra Suarez and Richard Vigesaa who assisted in the testing and training and to Theresa Cooney and Anne O'Hanlon who assisted in the data analysis.

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Differential Ability Decline and It's Remediation in Late Adulthood

Introduction

Since the beginning of scientific inquiry on the course of adult intellectual development one of the major questions raised has been the issue whether intellectual decline in late adulthood is uniform or ability-specific (Schaie, 1983). This question can be addressed by studying differential changes in average performance across the adult life-course, as well as by determining whether specific individuals show selective decline or decline across several abilities. To the extent that the observed ability decline may simply represent disuse of the intellectual skills involved in the measurement operations, it should be possible to remediate such decline by modest amounts of practice or remedial instruction. If decline is ability-specific, it also follows that attempts at remediating decline should follow a prescriptive ability-specific approach (cf. Willis, 1985).

The purpose of this presentation is twofold. In the first part we propose to discuss differential patterns of longitudinal change in adult intellectual performance that will illustrate the fact that maintenance and decline of abilities is not uniform, but depends upon the ability under study. Attention will also be called to the fact that these patterns are not invariant across time. The second part will be concerned with the results of recent cognitive training studies that provide data on the effects of practice and of cognitive training upon performance on ability variables for which longitudinal

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data on prior performance are available. It will therefore be possible to draw some conclusions not only on the differential patterns of decline, but also with respect to the extent to which such decline represents the consequences of readily remediable disuse, or must indeed be accepted as one of the inevitable concomitants of old age.

The Data Base

Subjects

Extensive cross-sectional and longitudinal data on human abilities have been collected in five waves (1956, 1963, 1970, 1977, 1984) over a twenty-eight year period as part of the Seattle Longitudinal Study (Schaie, 1983). In this study large random samples of subjects (Ns ranging from 500 to 1000) were drawn for each wave from the adult membership of a major health maintenance organization stratified by birth cohort. Our study participants range in age from the 20s to the 90s. At each successive assessment point, follow-up testing was conducted for as many previous participants as could still be retrieved. In addition to a cross-sectional data base now exceeding 3500 subjects, we now have longitudinal data also on substantial numbers of individuals who were followed for at least seven or fourteen years, and data on a smaller number of individuals who were followed for twenty-one or twenty-eight years. The data to be discussed in this presentation specifically involve a sub-set of 229 persons who were included in a cognitive training study (Schaie &

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Willis, 1985), for whom longitudinal data are available over the fourteen-year period from 1970 to 1984. Members of this sub-set ranged in age from 62 to 94 years, with a mean age of 72. These new data will be compared also with the previously reported fourteen-year longitudinal data covering the period from 1956 to 1970 (Schaie & Labouvie-Vief, 1974; Schaie & Parham, 1977).

Measurement Variables

Although embedded in a more extensive battery, the variables to be considered here are the first five primary mental abilities identified by Thurstone (1938) as measured by the 11-17 version of the SRA Primary Mental Abilities test (Thurstone, 1949) and/or its successor, the Schaie-Thurstone Adult Mental Abilities test (Schaie, 1985). These variables include Verbal Meaning, a word recognition test that assesses the indivdual's passive vocabulary; Spatial Orientation, a figure rotation task, assessing two-dimensional mental rotation skills; Inductive Reasoning, as measured by a letter series completion task; Number skills, as assessed by checking addition problems; and Word Fluency, which asseses active vocabulary by means of a recall task.

Procedure

During the first four waves of the longitudinal study, subjects were assessed in groups ranging from 5 to 25 subjects in one testing session lasting approximately two hours. In the 1984 study the test battery was expanded to include multiple markers of the ability variables to permit analyses at the latent construct (factor) level as

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well as to offer practice on the abilities of interest. The assessment battery therefore required a total of five hours examination time, that was spread across two sessions (the pretest). For purposes of the cognitive training study, subjects were classified into those persons who from 1970 to 1984 had declined by 1 SEM and those who had remained stable on the abilities of Spatial Orientation and Inductive Reasoning. Subjects who had declined only on one of the two abilities were assigned to a training program for that ability. Subjects who had remained stable or declined on both abilities were randomly assigned to one of the training programs. The training programs involved 5 one-hour individual tutorial sessions conducted in the participant's home. Training procedures involved modeling with concrete examples and practice with feedback on the strategies involved in successful performance on the target abilities. None of the training materials included items actually used in the assessment instruments. Within two weeks of completing their training program, all subjects were again assessed with the same five-hour test battery (posttest).

Patterns of Ability Decline

We have previously reported substantial differences in both peak attainment and decline of the primary mental abilities. With respect to the attainment of ability peaks we have also observed substantial gender differences. For example, women reach an adult plateau on Inductive Reasoning in their thirties, but continue to show gain on

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Verbal Meaning and Spatial Orientation until the early fifties. By contrast, men reach their average ability peak for numerical ability in their early thirties and for Spatial Orientation in their fourties. On Inductive Reasoning, their average peak performance actually does not occur until their early fifties. For both sexes, very few persons show reliably documentable decline until the sixties are reached, although there are small but statistically reliable average decrements for the seven-year interval from age 53 to age 67 for Space and Word Fluency (Schaie & Hertzog, 1983).

Our previous work was instrumental in showing that the linear age decrement on most abilities beginning in young adulthood found in earlier cross-sectional studies was an artifact of the increase in base level for successive cohorts in young adulthood. Our emphasis therefore had been in debunking the notion of universal ability decline. In this presentation, by contrast, we will deal only with that portion of the adult life span during which cognitive decline can be realiably observed in increasing proportions, albeit by no means for all, of the members of a study population. Given our earlier results, therefore, we will now discuss data on individuals who are in their sixties and older, all of whom have been tracked over fourteeen years. The age range covered in this discussion will extend from age 53 to 81.

Fourteen-year Longitudinal Changes

Although we have data on a few individuals over the entire twenty-eight years of our study, we have elected to cover the age

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range of interest more reliably by breaking the interval into two fourteen-year periods for which larger smaples are available. The first set of data to be considered, therefore, involves the replication of findings on longitudinal age changes over fourteen years for two successive fourteen-year periods (1956 to 1970 and 1970 to 1984). Figure 1 provides graphic representations of longitudinal age changes by ability. Although the primary concern here is with age changes, the reader will want to note that for all of the abilities except Word Fluency, virtually all data points for the most recent cohort will be found to lie above those for the earlier cohort; i.e., cohort differences for those cohorts born in 1941 or earlier continue to be shown in our most recent data.

But there are some other noteworthy departures from the previous findings with respect to patterns of age changes that merit particular attention. For *Verbal Meaning* we now observe small but realiable average age changes between ages 53 and 60, earlier then previously reported. On the other hand, we could not replicate the 1977 findings of earlier decline on *Spatial Orientation*. In our most recent cohort, significant average decline does not occur prior to age 60, and substantial decrement ensues only for the 74 to 81 year age interval. We replicate age 60 as the onset of modest average decline for *Inductive Reasoning* and for *Number*. More dramatic differences are found for *Word Fluency*. This ability was previously observed to be the first to show significant age decrement, and further it had been noted that earlier cohorts were actually at an advantage when compared to

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more recent cohorts. Note that the substantial decline for this ability from age 53 to 60 and from 67 to 74 could not be replicated. In the most recent cohort, decline on this ability now first occur s after age 60, and the rate of decline has slowed substantially. From these data we now find that average cumulative decrement from that age where it can first be reliably demonstrated to age 74, the age range whose occupants are often referred to as the "young-old", amounts to 3/4 of a population standard deviation for Number, less than half of a standard deviation for Verbal Meaning, Space and Reasoning and about 1/4 S.D. for Word Fluency. Cumulative decrement to age 81, the onset of advanced old age, is greater, of course. It amounts to approximately one population standard deviation for Verbal Meaning, Space and Number; to about 3/4 S.D. for Inductive Reasoning, and to less than 1/2 S.D. for Word Fluency.

Remediation of Ability Decline

The question next arises whether the observed patterns of decrement are irreversible concomitants of the aging process. Having shown substantial individual differences in the extent of ability decline and having related such differences to a variety of demographic and experiential variables (e.g., Gribbin, Schaie, & Parham, 1980; Schaie, 1984) it followed logically that we should attempt to bring such individual differences under experimental control. Cognitive training interventions with the elderly have been shown to be quite successful in a number of recent studies (cf. Baltes &

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Willis, 1982; Sterns & Sanders, 1980; Willis, 1985). What has been lacking in these studies, however, has been the availability of longitudinal data on the previous level of functioning of the trainees. That is, training gains could represent the remediation of past decrements or they could alternately involve raising performance over previously stable levels of function. If the training gains do represent remediation of previous decline, we still do not know, in the absence of prior data, whether the training has remediated all or only part of the deficit.

In our most recent training studies we have been able to address these question by classifying our participants into those who had either remained stable or who had shown reliable decline ($\pm$ 1 SEM) over the fourteen-year period preceding the intervention. An extensive test battery permitted assesment of training effects on the individual tests as well as at the latent construct (factor) level and showed substantial effects that involve both remediation of deficit and significant improvement of performance for those who had not declined (Schaie & Willis, 1985; Willis & Schaie, 1985). For the purpose of this presentation we will focus specifically on the effects of the training upon average performance levels to determine the effectiveness of our intervention in reversing intellectual decline in the elderly.

Because of the pre- post-test design of our training study, we have first of all data on the effects of practice on the *ability* between succesive test administrations (approximately two weeks

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apart). That is, as part of taking the test battery our participants spent approximately 20 minutes working on other items testing the relevant ability. For two of our abilities (Inductive Reasoning and Spatial Orientation), moreover, subjects received five hours of cognitive training with respect to the skills relevant in performing on one of these target abilities. To relate the training results to the age-specific ability-decline patterns we discussed earlier, we examined the decline-training gain relationship separately for three cohorts. Average ages for these cohorts at the time of intervention were 67, 74 and 81 years respectively. Note that for all of these samples statistically significant average decrement had been noted by age 67 on all five abilities under study.

Figure 2 provides graphic representations of the average decline over fourteen years and the effects of practice and cognitive training. Significant gains are found for all abilities at all ages. However, the magnitude of the gain differs across age groups, and consequently the extent to which our intervention succeeded in restoring or exceeding average performance values obtained at the 1970 base testing. Consider first those abilities for which only practice was provided. On *Verbal Meaning* practice was sufficient to remediate the loss experienced from age 67 to 74 for the middle cohort, and to raise the level of the younger cohort, at age 67, significantly above their level at age 53. However, practice did not suffice to remediate the loss shown by the oldest cohort. While they improve, their level remains significantly below their performance at the base point.

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Practice on *Number* did not suffice to return any of the groups to their 1970 level. However, the younger and middle cohort, were returned to their performance level shown in 1977 (a remediation then of the most recent seven-year decline). By contrast, full remediation occurred on *Word Fluency* for both the younger and middle cohorts.

Let us now turn to the abilities that were the target of cognitive training. Here we have estimated post-intervention levels, by incrementing the 1984 base value first by the average gain for those subjects who received only practice (test-taking), and then by the average gain of those subjects receiving both test-taking practice and cognitive training on the target ability. For *Spatial Orientation*, practice alone sufficed in remediating the fourteen-year decline for the younger and middle cohort. For those participants, however, who received the cognitive training remediation of average decline also occurred for the older cohort, and the younger cohort was raised to an average level that was significantly higher than observed at the base testing fourteen years earlier. Similar findings occurred for *Inductive Reasoning*. Here practice alone returned the younger cohort to the 1970 level, and the middle cohort to the 1977 level. Adding cognitive training, moreover, remediated the fourteen-year deficit for the older cohort, and raised the performance of the younger and middle cohort significantly above that experienced in 1970.

We had observed earlier that the occurrence of peak performance differed not only across abilities but was also gender-specific. It

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seems appropriate therefore to ask whether gender differences are also found in decline and remediation in old age. Figure 3 presents the relevant data for those abilities that were targets of our training. For *Spatial Orientation* we find an age by gender by training interaction. Gender differences in favor of men are significant for the young-old group (followed from mean age 53 to 67) through the practice phase, but gender differences are eliminated as a function of cognitive training. For the older grouyp (followed from age 67 to 81), however, there were no gender differences, except after training, which was more successful for the old-old women and raised their performance level above that of the men. Gender differences in favor of women were found for both groups on *Inductive Reasoning*. The difference in score level was maintained through both decline and reversal phase in the young-old group. In the old-old group, however, women showed a steeper drop as well as greater gain from practice and training.

Overlap in Score Distributions for Decline and Remediation

Discussions of mean differences in scores between groups or in the same group over time assume that the score distributions diverge from one another. The statistical tests that inform us on the reliability of such differences reflect, of course, sample size and variability. To understand the actual magnitude of differences, it may be more instructive to consider the degree to which score distributions diverge as a function of decline and converge as a function of

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intervention. To do so we standardized all observed scores on the two abilities for which training was conducted to the 1970 base. Figure 4 charts the frequency distributions at base, fourteen years later, and after intervention has occurred, separately for those subjects who met our stability/decline criterion. As would be expected, the score distribution for the stable subjects are virtually identical in 1970 and 1984, while the post-intervention distribution is shifted upwards. For the decliners, the 1984 distribution has shifted substantially below that occurring at base. Subsequent to the intervention the distributions shifts back towards the 1970 base; however, it is till located below that base level.

Making the assumption that the observed frequency distributions represent essentially random departures from normal distributions whose mean level has shifted, we can then estimate the proportion of scores that fall below the base distribution for the decliners as well as the proportion of scores that fall above the base distribution for the stables after intervention. Table 1 provides this information first for the scores of all subjects on the ability on which they were trained. Data are then given separately for each of the groups trained on Spacial Orientation or Inductive Reasoning. For the total group, age decrement on the target ability effects approximately one fourth of observed scores. Following intervention the total distribution is virtually back where it was at base, because the unremediated decline of some for the total group is balanced by the gain above base of the stables. When we consider these proportions

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separately for the gainers and decliners, we find that about two thirds of the decliners' scores that had dropped below the base distribution have been returned by the intervention, and that about one fifth of the scores of the stables are now above the limits of the base distribution. Comparing these data by separate ability it appears decline is somewhat greater for Spatial Orientation than for Inductive Reasoning, but that intervention gain is fairly equivalent across the two abilities..

Summary and Conclusions

We have analyzed differential patterns of ability decline by comparing data on longitudinal age change over the age range from 53 to 81 years from two successive fourteen year periods (1956-1970 and 1970 to 1984). Our most recent data once again replicates previously reported findings that significant age decrement does not begin until age 60. Findings for the different abilities vary by ability and cohort in magnitude of decline and at least for one ability (Word Fluency) also in rate of decline. In the most recent phase of our study, participants received cognitive training on one target ability (Inductive Reasoning or Spatial Orientation) and practice on the remaining abilities. Practice sufficed to reverse average performance drops from age 53 to 67 on all abilities except Number, and performance drops from age 60 to 74 on Verbal Meaning, Spatial Orientation and Word Fluency. Cognitive training further reversed the drop on Inductive Reasoning from 60 to 74, and the drop on Spatial

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Orientation and Inductive Reasoing from age 67 to 81. Examining score distributions, we found that for the group of subjects who had reliably declined over a fourteen year period about 40% of their scores fell below the 1970 base; about two thirds of this drop was reversed by practice and training. For those remaining stable, practice and training raised about 20% of their scores above the base distribution.

Just as we have cautioned against interpreting decline in means as evidence of universal decrement, so must we now caution against accepting the findings of mean gain and positive upward shifts of score distributions as evidence for a conclusion that age decrement in abilities can be reversed for all. On the positive side we can be elated by the finding that almost two third of our study participants who had declined benefited significantly from training and that better than one third of those who remained stable were able to raise their performance significantly. Evaluation in terms of the more stringent criterion of relating base performance to post-intervention outcome is somewhat more sobering. Our classification criterion for significant fourten=year decline (1 SEM from the 1970 base) on at least one ability was met by roughly 53% of our sample. Of these persons approximately 62% in turn met the reversal criterion of returning to within 1 SEM from their own base level. Thus subsequent to the intervention, approximately one third of our subjects would still be classifiable by our criterion as experiencing significant age decrement.

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We conclude then that for an increasing proportion of individuals decline on one or more abilities can reliably be documented. In young-old adulthood much of the observed ability decrement can be reversed for the majority of persons by modest interventions and may thus be seen to be a consequence largely of disuse of the skills assesed by our tests. As advanced old age is reached, however, ability decrement becomes more severe, and while remediable at least in part for most persons, can no longer be reversed for many persons in its entirety.

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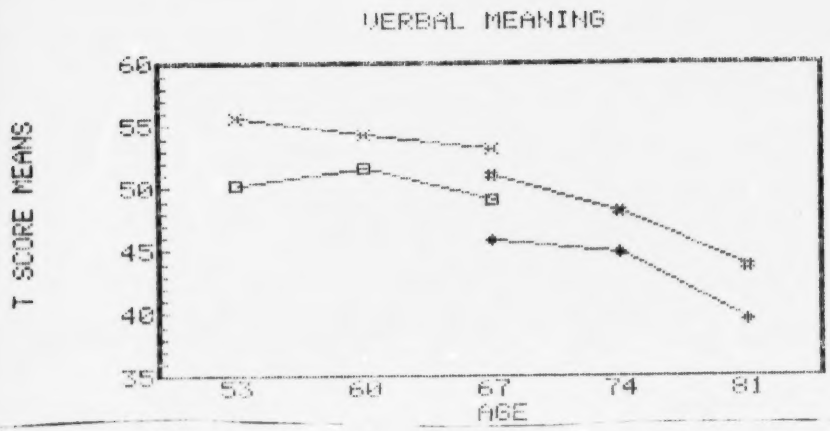

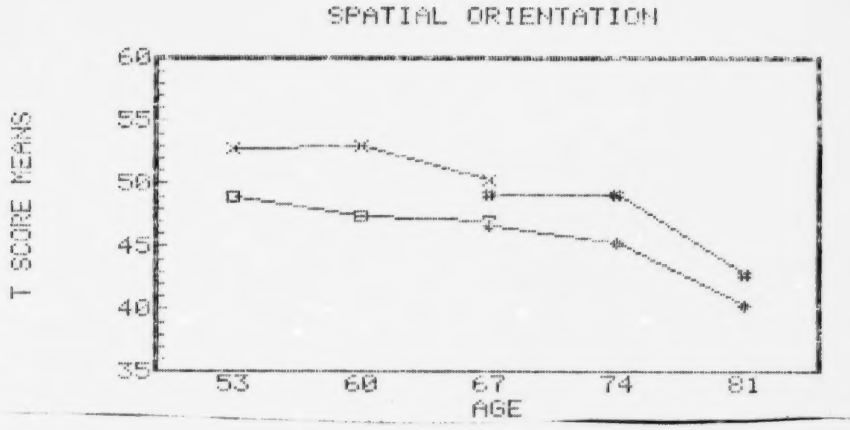

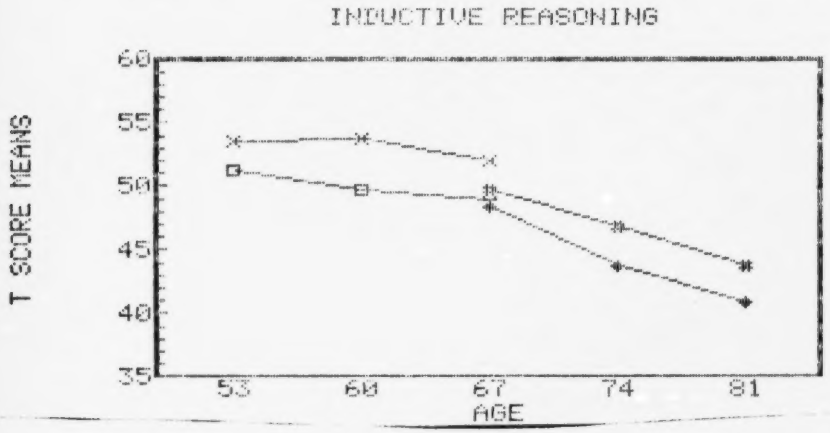

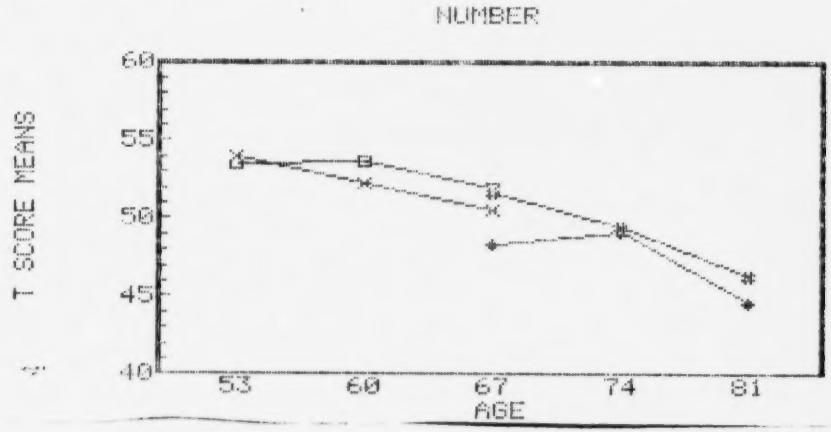

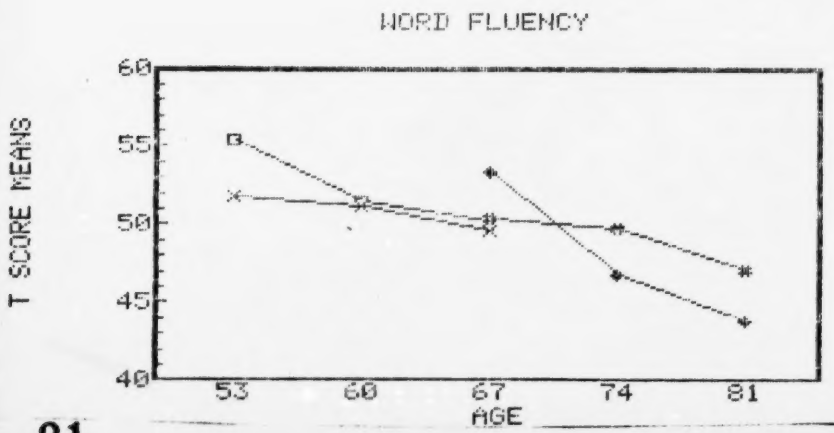

Figure 1. Fourteen-year longitudinal changes in two successive cohorts (Y = cohorts followed from age 53 to 67; O = cohorts followed from age 67 to 81).

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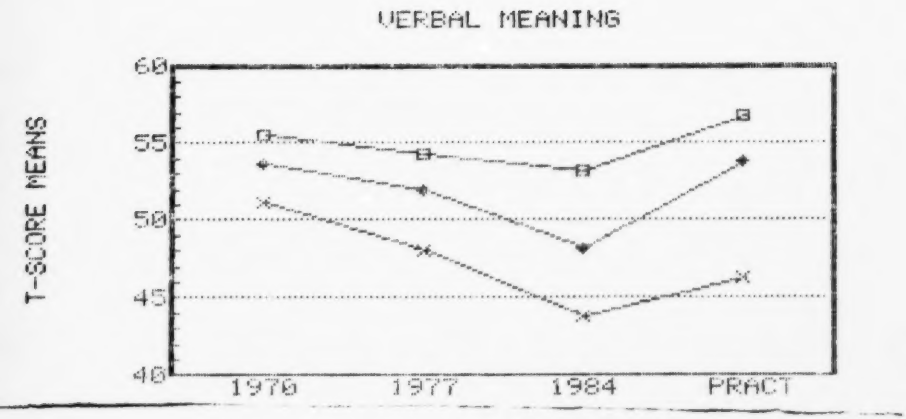

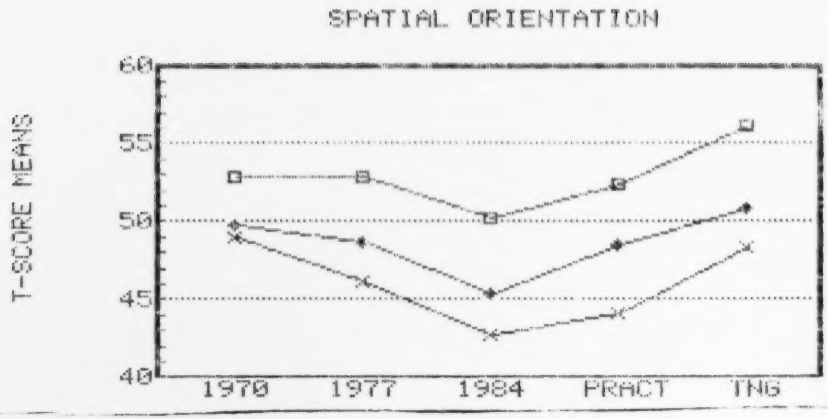

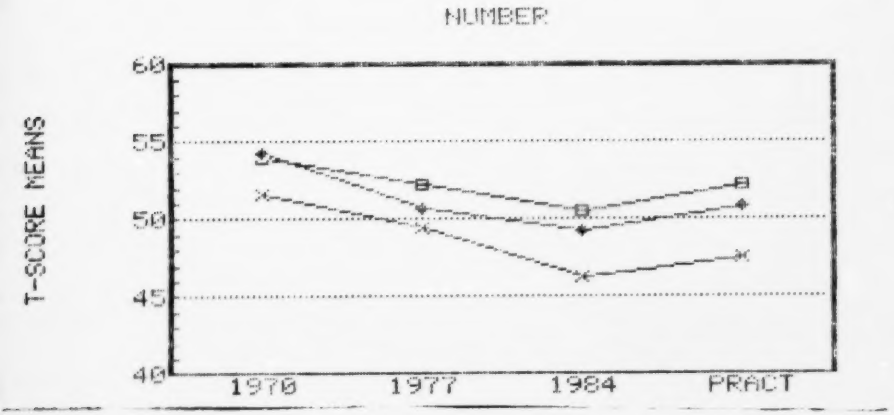

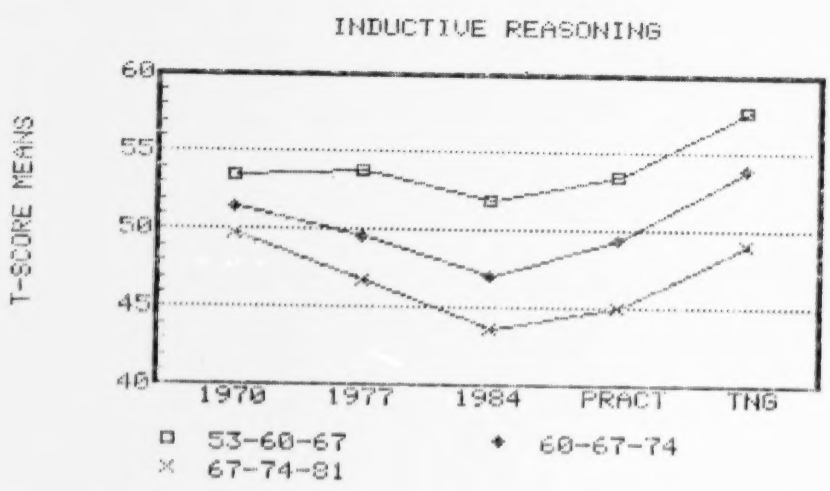

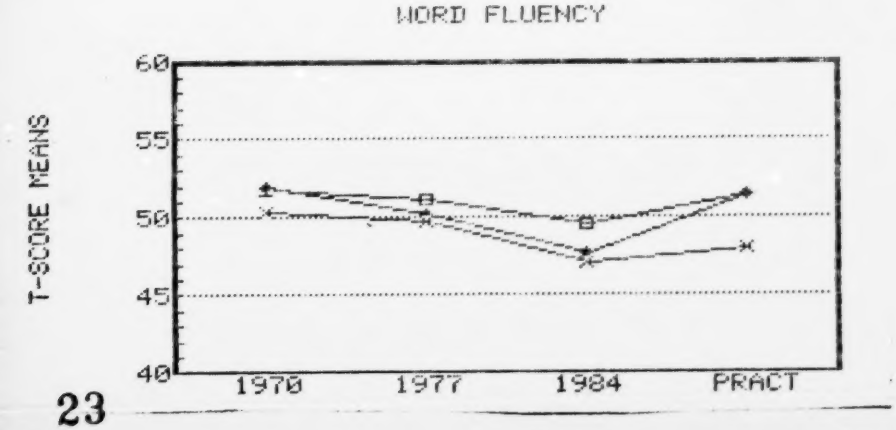

Figure 2. Average decline over fourteen years and average reversal due to practice and cognitive intervention in three cohorts (now aged 67, 74 and 81).

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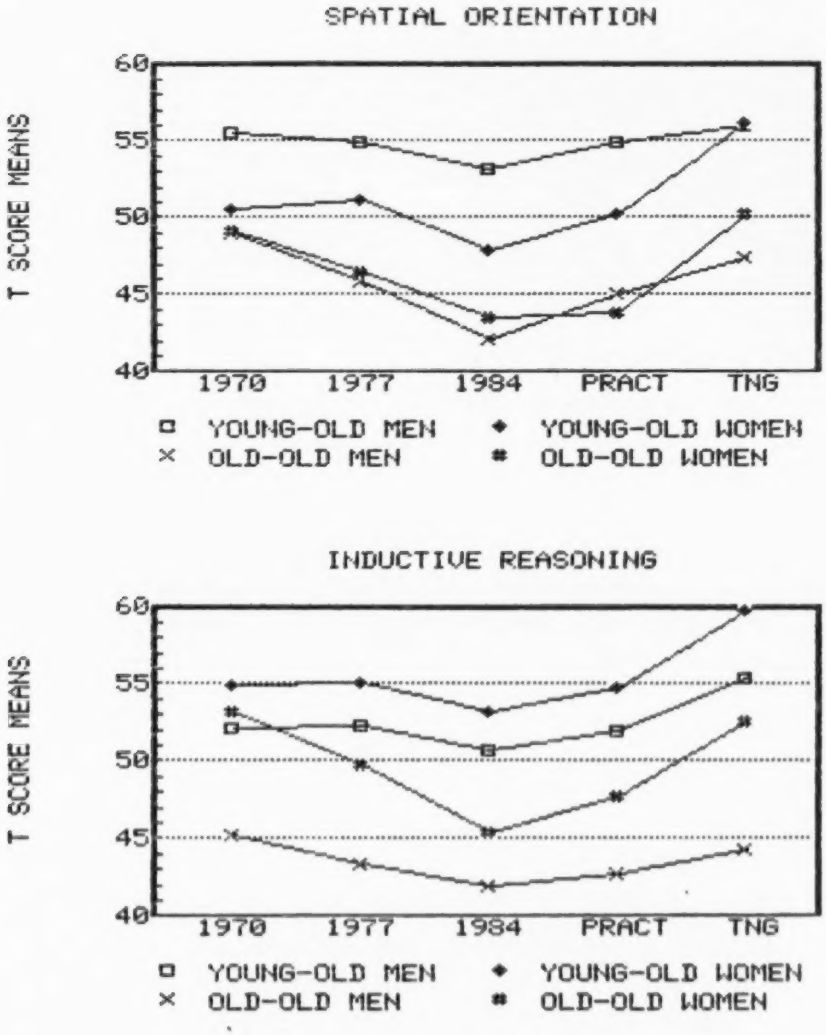

Figure 3. Age decline and reversal on Spatial Orientation and Inductive Reasoning by gender for two age groups (mean ages 67 and 81 in 1984).

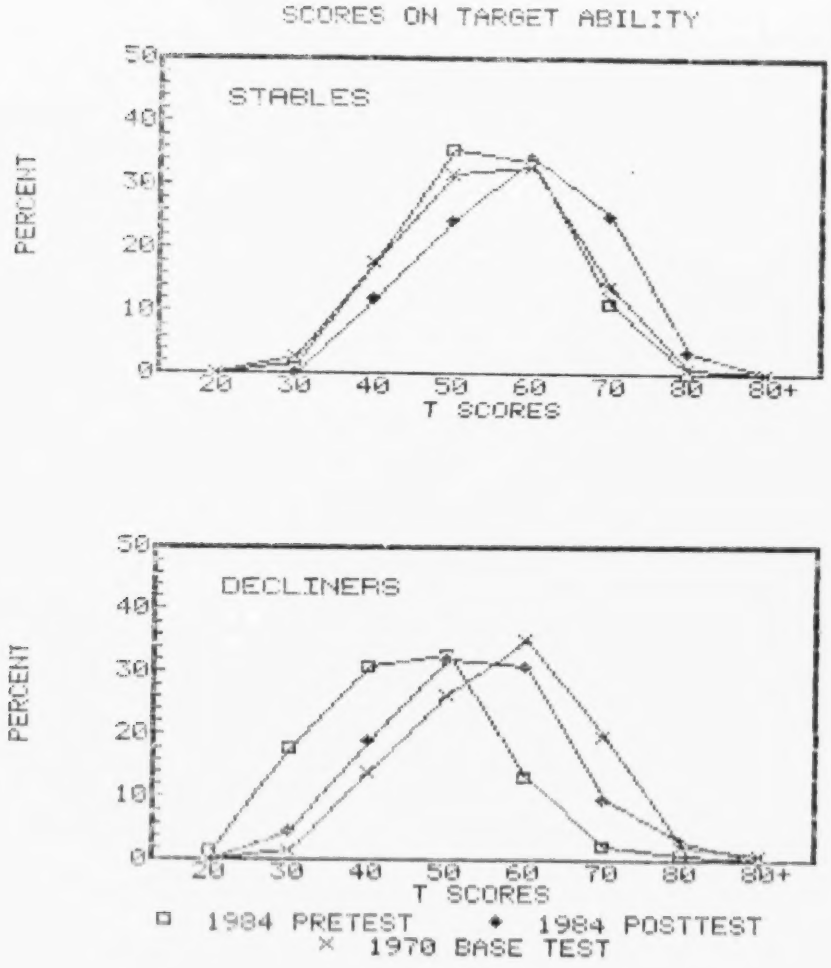

Figure 4. Frequency distributions of observed scores on target abilities at 1970 base assessment and in 1984 prior and subsequent to training intervention, separately for subjects remaining stable or declining.

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Table 1

Proportion of Scores at 1984 Pretest Falling Below or Above the 1970 Base Test Distribution

	Before Intervention	After Intervention
For Either Target Ability		
Entire Sample (N = 229)	- 24.9%	+ 2.0%
Stable Subjects (N = 107)	- 2.4%	+ 18.8%
Decliners (N = 122)	- 39.6%	- 13.1%
For Spatial Orientation Only		
Entire Sample (N = 118)	- 27.9%	+ 1.1%
Stable Subjects (N = 51)	+ 2.3%	+ 16.3%
Decliners (N = 67)	- 40.1%	- 14.3%
For Inductive Reasoning Only		
Entire Sample (N = 111)	- 21.4%	+ 5.2%
Stable Subjects (N = 56)	- 1.3%	+ 20.7%
Decliners (N = 55)	- 36/6%	- 11.6%

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